APPLICATION UNDER UNITED STATES PATENT LAWS

Atty. Dkt. No. PW 316313
(M#)

Invention: INTEGRATED OPTICS ARTIFICIAL CLADDING GRATING WITH A COUPLING VARIATION AND ITS REALISATION METHOD

Inventor (s): Christophe MARTINEZ

Pillsbury Winthrop Shaw Pittman LLP
Intellectual Property Group
P.O. Box 10500
McLean, VA 22102-4859

Attorneys
Telephone: (703) 770-7900

This is a:

☐ Provisional Application

☐ Regular Utility Application

☐ Continuing Application
☒ The contents of the parent are incorporated by reference

☐ PCT National Phase Application

☐ Design Application

☐ Reissue Application

☐ Plant Application

☒ Substitute Specification
Sub. Spec Filed March 15, 2006
in App. No. 10/538,140

☐ Marked up Specification re
Sub. Spec. filed ________
In App. No ____/____

SPECIFICATION

INTEGRATED OPTICS ARTIFICIAL CLADDING GRATING WITH A COUPLING VARIATION AND ITS REALISATION METHOD

FIELD

The invention relates to an integrated optics artificial cladding grating, with coupling variation and a method of manufacturing the same.

BACKGROUND

The use of optical grating is known in the field of optical fibres.

In this field, the optical cladding usually surrounds the fibre core and has a refractive index lower than that of the core to allow a light wave to spread in the core. Conjointly, the optical cladding permits the core to be held mechanically. The core of a fibre may not exist without the cladding.

Furthermore, the optical grating made in the fibre may permit one or more guided modes in the core of a fibre to be coupled to the fibre cladding mode(s) and vice versa. This grating is generally formed in the fibre core.

To vary the coupling of this type of grating, the size of the cladding may be modified in order to modify the effective index of the guided mode(s). (See, for example, U.S. Patent No. 5,420,948).

However, making cladding of variable size may be complex. Laser exposure techniques, stretching of the fibre or chemical etching, are generally used to make such a cladding. However, these processes may render the final component fragile.

Figure 1 shows a cross sectional view of such an optical fibre. In Figure 1, the light wave spreads in the z direction. This fibre is composed of a core 9 and cladding 11. The cladding has a first taper 11a in which a grating 13 is positioned. The narrowing of the cladding varies the effective index along the length of the grating, which creates

a "chirp" on the grating, which is to say a variation of the resonance wavelength along the grating.

The cladding then has a narrower zone 11b that has a consistent sized cross section, then a wider zone 11c permitting the narrower section of the cladding to be adapted to its normal section.

Modulating the size of the cladding may be obtained in Figure 1 by chemical attack or stretching fusion of the fibre.

In addition to the mechanical difficulties, the fibre core may not exist without the optical cladding. This dependence may limit the possibilities of changing the cladding parameters, gratings and solutions for design, architecture and integration of the gratings in complex systems.

SUMMARY

Embodiments of the invention include an integrated optics artificial cladding grating, with a coupling variation and a method of manufacturing such a grating. The cladding according to embodiments of the invention includes a robust structure and may provide more coupling variation possibilities.

An artificial cladding grating (ACG) as used herein refers to a zone of interaction created in a substrate, this zone of interaction comprising a core created in the substrate, a cladding created artificially in the substrate independently of the core and a grating. The grating may be capable of coupling the core mode(s) to one or more cladding modes and vice versa.

Embodiments of the invention have applications in all fields in which spectral filtering may be needed. For example, embodiments of the invention may be used for the manufacture of gain flatteners for optical amplifiers used, for example, in the telecommunications field. As another example, embodiments of the invention may be used for making

linear response filters with a wavelength on a spectral band defined for spectral recognition, in particular for measuring spectral offsets from power variation, for example, in the field of sensors.

Generally, the invention may particularly be well suited to all systems in which the use of spectral response filtering adapted to a specific requirement may be needed, this type of filtering generally requiring the development of an advanced filter.

In an embodiment of the invention, there is provided an artificial cladding grating wherein the optical cladding is independent from the guide core to which it is associated. By independence of the core and the cladding, it is meant that the core and the cladding may exist in a substrate independently from one another. In other words, the core may exist without the cladding and the cladding may exist without the core.

In an embodiment of the invention, an artificial cladding grating component for use in integrated optics, includes a substrate, an optical guide core, an optical cladding formed in the substrate, the optical cladding being independent of the core and surrounding at least a portion of the core, the optical guide core and the optical cladding forming a zone of interaction in the substrate, and a grating formed in the zone of interaction and constructed and arranged to couple a guided mode of the core to a cladding mode or vice versa. The zone of interaction is configured to provide coupling variation between the guided mode of the core and the cladding mode along the direction of propagation of the modes, and the refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core at least in the part of the cladding next to the core in the interaction zone.

By surrounding, it is meant that the fundamental mode profile of the core guide has a maximum that is included in

the index profile of the cladding. Thus, the profile of the fundamental mode of the core may be completely or partially included in the index profile of the cladding, which at structural level leads to a core situated anywhere in the cladding, including at its periphery, in which case the core may be partially outside of the cladding.

The coupling between the modes generated by the grating includes two main characteristics: the coupling wavelength and the coupling force or coupling efficiency. In an embodiment of the invention, these characteristics may be changed.

Thus, according to an embodiment of the invention, the coupling variation along the propagation direction of the modes may be a variation of the coupling force (or coupling efficiency) and/or of the coupling wavelength. This variation is such that it may permit desired luminous spectra to be obtained at the output of the zone of interaction in the cladding and/or in the core.

This coupling variation may thus permit the use of the artificial cladding grating of the invention in a large number of components, taking into account that the coupling may thus be adapted to the desired application.

Different embodiments of this variation, which may be combined with one another, may be envisaged.

According to a first embodiment, the coupling variation of the artificial cladding grating is obtained by modulation of the section of the cladding in the interaction zone.

According to a second embodiment, the coupling variation of the artificial cladding grating is obtained by variation of the centering of the core with respect to the section of the cladding. In fact, it may be possible to change the relative position of the core with respect to the cladding or the cladding with respect to the core.

The coupling by a grating between different modes takes place for determined wavelengths λ_j defined by the following known relation:

$$\lambda_j = \Lambda \text{ x } (n_0 - n_j) \quad (1)$$

where:

– n_0 is the effective index of the guided mode 0 in the core,

– n_j is the effective index of the cladding mode number j,

– λ_j is the resonance wavelength for the coupling in mode j, and

– Λ is the grating period.

This coupling causes an energy transfer between the guided mode of the core and the cladding mode(s) for the central wavelength λ_j or vice versa. The energy coupled in the cladding modes may then be guided in the cladding. The same approach may be applied for the coupled mode in the core.

λ_j may be modified by setting the parameters of Λ and/or the distribution of the effective indices of the different modes.

Furthermore, the efficiency of the coupling between the modes depends on the length of the grating and the coupling coefficient K_{0J} between the modes 0 and j. This coefficient is given by the spatial recovery integral of the modes 0 and j, weighted by the index profile induced by the grating. The following relationship may be obtained:

$$K_{0J} \propto \iint \xi_0 . \xi_J^* . \Delta \Delta n s \quad (2)$$

where:

30532728v1

- ξ_0 and ξ_j are the transversal profiles of the modes 0 and j and ξ_j^* the complex conjugate of ξ_j,

- Δn is the amplitude of the effective index modulation induced by the grating in a plane perpendicular to the direction of propagation of the modes, and

- ds is an integration element in a plane perpendicular to the direction of propagation of the modes.

K_{0j} may be modified by varying the profile of the modes and/or the index profile induced by the grating. In other words, K_{0j} may be modified by varying the opto-geometrical characteristics of the cladding.

The larger the cladding dimensions and index level are, the more cladding modes will be accepted for propagation and the more filtering spectral bands will be possible. This may be beneficial when searching for multiple filtering or to have more leeway when choosing a filtering mode.

In order to limit the number of cladding modes that can be coupled, it may be useful to reduce the opto-geometrical dimensions of the cladding.

The dimensions and index level of the core may condition the characteristics of the propagating mode. Furthermore, the larger the index differences between the core, the cladding and the substrate, the greater the chance of potentially having couplings for low grating periods, as shown by the equation (1) (at a given resonance wavelength, the period is inversely related to the index difference between the guided mode of the core and the cladding mode).

By modifying the position of the core, the grating and the cladding, it may be possible to generate different couplings. As can be seen in equation (2), the coupling force (or coupling efficiency) depends on the relative position, in the plane transversal to the direction of propagation of the profiles of the cladding mode, of the guided mode in the core and the grating.

As the parameters related to the grating may be more difficult to control than those related to the cladding, it may be beneficial to create a grating with a consistent pattern of period and/or amplitude and modify the other coupling parameters such as the opto-geometrical dimensions of the cladding and the core decentration.

With respect to the decentration of the core, it will be appreciated that if the core mode and the cladding mode as well as Δn have symmetrical profiles, the coupling coefficient is generally not zero. In this case, it can be shown that a decentration of the core with respect to the cladding only slightly changes the value of K.

If, on the other hand, a coupling between a symmetrical fundamental mode and a non-symmetrical fundamental mode occurs, the recovery integral is nil. In this case, the presence of a decentration between the core and the guide increases K. It may then be shown that this variation of K depends on the decentration δx. However, this variation of K slightly depends on the variation of the size of the cladding.

Moreover, it will be appreciated that creation of the integrated optics artificial cladding grating enables the cladding to be obtained by modification of the refractive index of the substrate, in particular by implantation or ionic exchange. Consequently, the desired form of the cladding may be obtained without conventional etching or stretching, but, for example, with a mask including a suitable pattern.

As a result, manufacturing of the component is simpler and a robust component may be obtained.

Furthermore, it will be appreciated that the cladding and the core may exist independently from one another in the substrate. This, in turn, provides more flexibility when creating the final component and easier integration of this component in a complex architecture. In particular, it will be appreciated that the core may no longer be situated in the cladding outside of the zones of interaction, but solely in

the substrate, which permits optical isolation of the core. In this way, the cladding may only act on the propagation of a light wave in the associated guide core in the part surrounding the core. As a result, the cladding may guide or transport light waves independently of the core. This independence between the core and the cladding may also permit a greater number of combinations to be created by varying not only the size of the cladding but also the position of the core in the cladding.

In an embodiment of the invention, the grating formed in the interaction zone, may comprise one or more elementary gratings. By elementary grating, it is meant a grating having substantial constant structural parameters.

In an embodiment, the grating may be made by direct disturbance of the guide core, for example, by segmentation of the core and/or by variation of the core section. The grating may also be obtained by indirect disturbance of the core, such as surface etching of the substrate, segmentation of the cladding and/or variation of the cladding section. It will be appreciated that these different embodiments may be combined with one another.

Consequently, apodised or chirped type gratings may thus be made.

The substrate may be made from a single material or by superposition of several layers of materials. In the latter case, the refractive index of the cladding is different from the refractive index of the substrate at least with respect to the neighboring layers of the cladding.

In an embodiment, the cladding has a refractive index higher than that of the substrate.

According to an embodiment of the invention, the guide may be a planar guide, when the confinement of the light takes place in a plane comprising the direction of propagation of the light. Alternatively, the guide may be a microguide, when

the confinement of the light takes place in two directions transversal to the direction of propagation of the light.

According to an embodiment of the invention, a light wave introduced in the core of an artificial cladding grating is filtered in the zone of interaction. One or more guided modes of the light wave introduced in the core may be coupled in the zone of interaction, by the grating, to one or more cladding modes associated to this zone, for wave lengths λ_j defined in the relationship (1). The coupled part of the light wave in the one or more cladding modes may be recovered or not when it leaves the cladding and the non-coupled part of the wave continues to be transported by the core at the output of the interaction zone. The core may be connected to an optical component. The same approach may be applied when the light wave is introduced in the cladding.

The artificial cladding grating of embodiments of the invention may be used to manufacture a gain flattener. In this case, it is desirable that the coupling variation be such that a light wave comprising several spectral bands of different amplitudes, after passing through the zone of interaction is transformed into a light wave whose spectral bands all have more or less the same amplitude.

By spectral band, it is meant a band with a set of wavelengths with a determined central wavelength and bandwidth, a light wave being able to comprise one or more spectral bands.

The use of such a component may be of particular interest in an optical amplifier, in order to recover at the amplifier output a light wave whose spectral bands all have the same amplitude.

The artificial cladding grating of the invention may also be used to manufacture a linear filter. A linear filter is a filtering component whose spectral transfer function is linear with respect to the wavelength. The use of such a component permits, for example, to stabilize the frequency of a laser

source. In particular, when a laser signal with a narrow spectral band around a central wavelength λ_0 is transmitted through a suitable filter made according to an embodiment of the invention, the filter outputs a signal proportional to the wavelength: $T(\lambda 0)=a\lambda_0+\beta$ where β is a constant. The slightest spectral offset in either direction of the spectrum may then create a drop or an increase in the output signal. A servo control for this output signal to a laser control acting on the spectral position of the emission may be created and the source may thus be stabilized. An artificial cladding grating and a photo-detector may be used to stabilize the laser source. A spectrum analyzer is no longer of use.

According to one embodiment, the cladding and/or the guide core and/or the grating may be made using technique permitting the refractive index of the substrate to be modified. For example, ion exchanges techniques, ionic implantation and/or radiation, e.g., by laser exposure or laser photo inscription (the radiation produces local heating) or even depositing of layers, may be used.

The ion exchange technology in glass may be of particular interest. However, it will be appreciated that other substrates than glass may be used such as, for example, crystalline substrates of the KTP or $LiNbO_3$ types, or even $LiTaO_3$.

More generally, the grating may be made using any techniques permitting the effective index of the substrate to be changed. In addition to the techniques already mentioned, substrate etching techniques for making gratings may also be used. Such etching may be carried out above the cladding or in the portion of cladding of the zone of interaction and/or in the core portion of the interaction zone.

The grating pattern may be obtained either by laser sweeping in the case of radiation being used, or by a mask. The latter may be the mask, which permits the core and/or the

cladding to be obtained, or a specific mask to make the grating.

In an embodiment of the invention, there is provided a process for making an artificial cladding grating as previously defined, the cladding, the guide core and the grating being made respectively by modifying the refractive index of the substrate so that at least in this part of the cladding next to the core and at least in the interaction zone, the refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core, so that this zone of interaction has a coupling variation along the direction of propagation of the modes.

According to one embodiment, the process of the invention comprises the following acts:

a) introduction of a first ionic species in the substrate so as to permit the optical cladding to be obtained after act c) (i.e., the burying),

b) introduction of a second ionic species in the substrate so as to permit the guide core to be obtained after act c),

c) burying the ions introduced in acts a) and b) so as to obtain the cladding and the guide core, and

d) making the grating.

It will be appreciated that the order of these acts may be inverted.

The introduction of the first and/or second ionic species may be performed by an ionic exchange, or by ionic implantation.

The first and the second ionic species may be the same or different.

The introduction of the first ionic species and/or the introduction of the second ionic species may be performed with the application of an electrical field.

In the case of an ionic exchange, it is desirable that the substrate contains ionic species capable of being exchanged.

According to one embodiment, the substrate is glass and contains Na^+ ions introduced beforehand, the first and the second ionic species are Ag^+ and/or K^+ ions.

According to one embodiment, act a) comprises the creation of a first mask comprising a pattern capable of obtaining the cladding, the first ionic species being introduced through this first mask and act b) comprises the elimination of the first mask and the creation of a second mask comprising a pattern capable of obtaining the core, the second ionic species being introduced though this second mask.

The masks used in the invention are for example made of aluminium, chrome, alumina or a dielectric material.

According to a first embodiment, in act c), the first ionic species is buried at least partially prior to act b) and the second ionic species is buried at least partially after act b).

According to a second embodiment, in act c), the first ionic species and the second ionic species are buried at the same time after act b).

According to a third embodiment, in act c), the burying comprises a deposit of at least one layer of refractive index material lower than that of the cladding, on the surface of the substrate.

It will be appreciated that this mode may be combined with the two previous modes.

In an embodiment of the invention, at least part of the burying is carried out with the application of an electrical field.

Generally before burying under the electrical field and/or the depositing of a layer, the process of the invention may further comprise burying by re-diffusion in an ionic bath.

This re-diffusion may be partially carried out before act b) to re-diffuser the ions of the first ionic species and partially after act b) to re-diffuse the ions of the first and second ionic species. This re-diffusion may also be carried out completely after act b) to re-diffuse the ions of the first and second ionic species.

By way of example this re-diffusion may be obtained by plunging the substrate in a bath containing the same ionic species as that contained beforehand in the substrate.

Act d) for creating the grating may be carried out independently of acts a) and b) or be carried out simultaneously during act a) and/or act b).

Other characteristics and advantages of the invention will become clearer from the following description, with reference to the figures of the appended drawings. This description is provided by way of illustration and is in no way restrictive.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a schematic representation of a grating in an optical fibre, which includes an optical cladding comprising a variation in section,

Figure 2 schematically shows a cross section of an artificial cladding grating according to an embodiment of the invention in which the section of the cladding varies discontinuously as well as the centering of the core in the cladding,

Figure 3 schematically shows a cross section of an artificial cladding grating according to an embodiment of the invention, in which only the section of the cladding varies continuously,

Figure 4 schematically shows a cross section of an artificial cladding grating according to an embodiment of the invention, in which the centering of the core in the cladding varies continuously,

Figure 5 schematically shows a cross section of an artificial cladding grating according to an embodiment of the invention, in which the section of the cladding as well as the centering of the core in the cladding vary continuously,

Figure 6 schematically shows a cross section of an artificial cladding grating according to an embodiment of the invention, in which the centering of the core in the cladding varies continuously,

Figures 7a to 7d shows a manufacturing process of an artificial cladding grating according to an embodiment of the invention,

Figures 8a to 8d diagrammatically shows variants of embodiments of the mask pattern permitting a grating to be made, and

Figure 9 shows a cross section of an artificial cladding grating according to an embodiment of the invention with a grating in the cladding.

DETAILED DESCRIPTION

Figure 2 schematically shows a cross section of an artificial cladding grating according to an embodiment of the invention in which the section of the cladding varies as well as the centering of the core in the cladding.

This cross section is made in a plane parallel to the surface of the substrate and containing the direction z of the propagation of the light wave in the core.

In Figure 2, a substrate 20 includes an optical cladding 3, a guide core 2 and a grating 19.

The optical cladding 3 is independent from the core and surrounds part of the core in a zone of the substrate called the zone of interaction I1 comprising the grating 19.

In this embodiment, the grating is formed in the core 2. Furthermore, the cladding includes 4 parts respectively

referenced 3a, 3b, 3c, 3d called elementary claddings which are placed in series. These elementary claddings have different sizes and centre positions at the guide core.

In this way, by modifying the size of the elementary claddings and the decentration of the core with respect to these elementary claddings, it may be possible to obtain an evolved type grating.

In this embodiment, the guide core 2 and the grating 19 are uniform along the length of the interaction zone. Only the form of the cladding and its position with respect to the core change. This change is made by steps due to the differences between the elementary claddings and permits the coupling in the interaction zone to be varied.

This type of artificial cladding grating may be used for example to create filtering characteristics capable, in particular, of creating a gain flattener, which may be used in optical amplifiers, or a linear response filter.

In general, the principle of placing in series elementary claddings surrounding a same guide core may be extended to the principle of a cladding whose position and/or size vary uniformly with respect to the core (and not by step/level or discrete as in Figure 2). Figures 3, 4 and 5 are examples of this.

These figures are cross sections in a plane parallel to the surface of the substrate and containing the direction z of propagation of the light wave in the guide core.

Figure 3 shows a substrate 20 including a cladding 31, a guide core 21 and a grating 41, formed in the core.

The zone of interaction I2 corresponds to the zone of the substrate, which simultaneously comprises the cladding, the core and the grating.

The coupling variation along the direction z of propagation of a light wave in the core is obtained in this example by varying the cladding section in this direction. More precisely, the width of the cladding, as shown in the

plane of the figure, is reduced from a maximum value at the end 31a of the cladding, to a minimum value at its other end 31b. This variation of the cladding width may be defined along the pattern of the grating according to a continuously variable function. Consequently, the coupling wavelength is also continuously variable (chirp effect) along the grating.

Figure 4 shows an artificial cladding grating in accordance with an embodiment of the invention. In Figure 4, the variation of the coupling is obtained by decentration of the cladding with respect to the core, the section of the cladding being constant. In Figure 4, the substrate 20 includes an optical cladding 32, a guide core 22 and a grating 42. The zone of interaction formed from these three 3 elements is identified with the reference I3. The form of the cladding is such that its axis of symmetry 15 in the plane of Figure 4 is decentered with respect to the centre of the cladding, with respect to the direction z, corresponding to the axis of symmetry of the core 22. The two ends 32a and 32b of the cladding on the other hand are progressively recentered in this direction z (in other words at the ends of the cladding, the axis 15 and the direction z are the same) so as to reduce the coupling coefficient.

In this embodiment, the artificial cladding grating excites a non-symmetrical profile mode; it is an apodised type grating. This type of component is characterized by a grating whose coupling efficiency slightly decreases at its ends. Consequently, there is no discontinuous phenomenon in the coupling and the spectral response of the filter has much smaller secondary lobes than in the case of a standard grating.

It will be appreciated that the two previous examples may easily be extrapolated by those skilled in the art to create an artificial cladding grating that is both apodised and chirped.

Figure 5 shows an artificial cladding grating according to an embodiment of the invention, whose coupling variation is obtained by varying both the size and the position of the cladding with respect to the core, along the grating.

The substrate 20 includes a guide core 23, an artificial cladding 33 surrounding the core in a zone of interaction I4, and a grating 43 formed in the core 23 in the zone of interaction I4. In this zone of interaction I4, it can be seen that the cladding has a variable section, which tapers down from its end 33a towards its other end 33b. Furthermore, the axis of symmetry 16 of the cladding in the plane of Figure 5 is not the same or parallel to the direction z of propagation in the core which is linear in the interaction zone. The axis 16 and the direction z are secant in the zone of interaction such that the cladding has a variable decentration in the zone of interaction I4 with respect to the core.

A coupling variation may also be obtained in the interaction zone by using a cladding of constant section and by varying the decentration of the core with respect to the cladding, as shown in the embodiment of Figure 6.

Figure 6 is a schematic cross section in a plane parallel to the surface of the substrate that contains the direction z of propagation.

Figure 6 shows a substrate 20 including a cladding 34, a guide core 24 and a grating 44, which is part of the core in a zone of interaction I5 that is defined by a zone of the substrate in which the cladding surrounds the core. In this embodiment, the axis of symmetry of the cladding in the plane of Figure 6 is the same as the direction z de propagation while the axis of the core 54 is in this specific case the same as the direction z solely in the part which does not contain the grating. This axis 54 does not coincide with the z direction in its part, which contains the grating.

Thus, the part of the core containing the grating turns away from the direction z then turns towards it until it again joins the z direction, such that the guide core is decentered with respect to the cladding. This decentration leads to a coupling variation.

It will be appreciated that the various embodiments of artificial cladding grating described above may be combined with one another. Furthermore, in these various embodiments, the grating is part of the guide core. However, it will be appreciated that the grating may be part of the cladding and/or in the core or even in the substrate.

Furthermore, it will be appreciated that the component of the invention may be integrated into a more complex optical architecture such as that of an optical amplifier to create, for example, a gain flattener or a linear filter. The set of elements of these architectures may or may not be created on the same substrate as the component of the invention.

Figures 7a to 7d show a method of manufacturing an artificial cladding grating according to an embodiment of the invention, using the ion exchange technology.

These figures are cross sections in a plane perpendicular to the surface of the substrate and perpendicular to the direction z of propagation. Figures 7a-d contain an interaction zone, for example, the zone of interaction I1 containing the elementary cladding 3d of Figure 2.

Figure 7a shows the substrate 20 containing ions B.

A first mask 61 is made for example by photolithography on some faces of the substrate. This mask comprises an opening that is determined according to the form and dimensions (width, length) of the cladding 3 that is to be produced.

A first ionic exchange is then carried out between ions A and ions B contained in the substrate, in a zone of the substrate located close to the opening on the mask 61. This exchange may be obtained for example by soaking the substrate

30532728v1

fitted with the mask in a bath containing ions A and possibly by applying an electrical field between the face of the substrate on which the mask is placed and the opposite face of the substrate. The zone of the substrate in which this ionic exchange takes place forms the cladding, which may have non-uniform dimensions, form and/or may have variable centring.

To bury this cladding, ions A may be re-diffused with the use of, e.g., an electrical field, applied as previously described. Figure 7b shows the cladding after it has been partially buried. The mask 61 is generally removed prior to this burying step.

The creation of the cladding according to the invention may be similar to that of a guide core but with different dimensions.

In Figure 7c, a new mask 65 is formed on the substrate for example by photolithography, after possible cleaning of the face of the substrate on which it is created. This mask comprises patterns capable of allowing a guide core 19 to be made and in particular when the core comprises a grating, the patterns of the mask 65 may be adapted to the patterns of the grating to be formed.

A second ionic exchange is then carried out between ions B of the substrate and ions C which may or may not be the same as ions A. This ionic exchange may be carried out as previously described by soaking the substrate in a bath containing ions C and by possibly applying an electrical field.

Finally, Figure 7d shows the component obtained after the core 19 has been buried, by re-diffusing the ions C and final burying of the cladding, with or without the use of an electrical field. The mask 65 is generally removed prior to this burying act.

The conditions of the first and second ionic exchanges are defined so as to obtain desired differences of refractive indices between the substrate, the cladding and the core. The

adjustment parameters of these differences may be the exchange time, the temperature of the bath, the concentration of ions of the bath and the presence or absence of an electrical field.

By way of example of an embodiment, the substrate 20 is made of glass containing Na^+ ions, and the mask 61 is made of aluminum.

In an embodiment, the first ionic exchange is performed with a bath containing Ag^+ ions at approximately 20% concentration, at a temperature of approximately 330°C and for an exchange time of around 5 minutes. The ions are re-diffused first in open air at a temperature of approximately 330°C for 30 s, then the cladding thus formed in the glass is partially buried. This burying is carried out by re-diffusion in a sodium bath at a temperature of approximately 260°C. The duration of this step depends on the desired depth of burying for the final component. Consequently, for a surface component, a duration of approximately 3 minutes is sufficient, whereas for a buried component a duration of approximately 20 minutes may be chosen. In this second case, it may also be desirable to bury the cladding under electric field before the second exchange. In an embodiment, a current of 20 mA is applied between two sodium baths on either side of the plate at a temperature of 260°C and for 10 minutes.

The mask 65 may also be made of aluminum.

The second ionic exchange may be performed with a bath also containing Ag^+ ions at approximately 20% concentration, at a temperature of approximately 330°C and for an exchange time of approximately 5 minutes. The ions are first re-diffused in open air at a temperature of approximately 330°C and for 30s. Then partial burying may be carried out, of the core thus formed in the glass by re-diffusion in a sodium bath at a temperature of approximately 260°C for 3 mn. For a buried component, this step is not necessary.

The final burying of the cladding and the core may be carried out with the use of an electrical field, with the two opposite faces of the substrate in contact with two baths (in this example sodium) capable of allowing a potential difference to be applied between these two baths. For a surface component, a duration of less than one minute is sufficient, and in the case of a buried component a duration of around 30 minutes may be used. The burying may be carried out with a current of 20 mA at 240°C.

Many variants of the previously described process may be performed. In particular, the burying acts of the cladding and the core may be carried out as previously described during 2 successive acts. It will be appreciated that they may also be carried out simultaneously in certain cases. The core having a higher ionic concentration than that of the cladding, it is buried more quickly than the cladding, which also permits possible centering of the core in the cladding.

The difference of concentration between the core and the cladding may generally be obtained either by re-diffusing in a bath the ions forming the cladding or by a difference of concentration of the ions introduced in acts a) and b).

As previously discussed, to bury the cladding and the core, a layer of material 68, shown in dotted lines on Figure 7d, may be deposited on the substrate 20, in an embodiment of the invention. It is desirable that this material has a refractive index lower than that of the cladding, in order to permit optical guidance.

It will be appreciated that the creation of the component according to embodiments of the invention is not limited to the ion exchange technique. The component may be made using any techniques, which permit the refractive index of the substrate to be modified.

Furthermore, as previously discussed, the period, size and position of the grating, with respect to the core and to

the cladding, are parameters that can be adapted to suit the applications.

The pattern of the grating may be defined on the mask allowing the cladding to be made and/or on the mask allowing the core to be made or even on a specific mask for solely creating the grating.

Figures 8a to 8d illustrate several masks M1, M2, M3, M4 that may be used to create a grating in accordance with an embodiment of the invention. These figures are top views of the masks and show the parts of the masks which allow the grating to be made. The white zones of the pattern of the masks correspond to the openings of the masks.

With these masks, a periodic grating of period Λ may be obtained. Masks M1 and M4 may be used to form a grating by segmentation while masks M2 and M3 may be used to form a grating by variation of the width of the patterns.

These masks may be specifically used to create the grating in the core and/or in the cladding or even in the substrate. Alternatively, part of the masks may be used to form the core and/or the cladding, the grating then being created at the same time as the core and/or the cladding.

Figures 2 to 6 previously described show examples of gratings formed in the guide core.

Figure 9 shows an artificial cladding grating according to an embodiment of the invention whose grating is created by segmentation of the cladding 35.

In Figure 9, the grating is formed in the cladding by alternating the period Λ of zones 46 with different refractive indices from that of the rest of the cladding. Zones 46 have a variable length, as viewed in the direction z of propagation of a light wave in the core 25. Furthermore, the width of the cladding considered in a direction perpendicular to the direction z may also be variable to obtain a variable coupling. The core, as in the previous examples pass through the cladding, the grating being consequently also included in

the core. In other words, the core also comprises zones with different refractive indices from that of the rest of the core.

The gratings may be formed by using conventional techniques permitting the effective index of the substrate in the core and/or in the cladding to be modified locally.

They may therefore be created during the ionic exchanges permitting the core and/or the cladding to be made or during a specific ionic exchange. They may also be obtained by etching the zone of interaction on the substrate or by radiation. In particular, the gratings may be obtained by exposure of the core and/or the cladding to a CO_2 type laser. The laser produces local heating permitting the ions to be re-diffused locally and thus include the pattern of the gratings.

By way of example, the substrate may be swept with a laser beam that is, for example, amplitude modulated so as to introduce a modulation of the grating at the desired pitch.